

## **A TESTBED FOR NUCLEAR EXPLOSION MONITORING RESEARCH AND DEVELOPMENT**

Robert L. Woodward, David H. Salzberg, Robert G. North  
Center for Monitoring Research  
Science Applications International Corporation

Sponsored by The Defense Threat Reduction Agency  
Arms Control Technology Division  
Nuclear Treaties Branch

Contract No. DTRA01-99-C-0025

### **ABSTRACT**

The Research and Development Testbed (R&D Testbed), developed within the Defense Threat Reduction Agency's (DTRA) Center for Monitoring Research (CMR), is designed to support US national and international nuclear test monitoring and verification needs by providing several key functions to the R&D community. First, the R&D Testbed supports the Department of Defense (DoD) sponsored research and development community by providing an interface to the wide range of resources available at CMR. For example, the R&D Testbed provides access to CMR resources such as: near-real time waveform data from International Monitoring System (IMS) and GSETT3 stations, multi-terabyte seismic, hydroacoustic and infrasonic waveform archives, specialty ground-truth calibration databases, research archives, high resolution gamma-ray spectroscopy and beta-gamma coincidence spectroscopy radionuclide databases, and past and present products of both the Prototype International Data Center and the International Data Centre (IDC).

A second R&D Testbed function is to provide a centralized repository and exchange mechanism for research results generated by DoD sponsored researchers, facilitating the exchange of results among the R&D community. Uniform acceptance criteria and validation testing are applied to all results delivered to the R&D Testbed, thus ensuring easy and reliable use of these results by others. Further, centralized storage ensures that valuable research results accumulate through time--preventing their loss and avoiding their duplication. Deliveries to the R&D Testbed can take a variety of forms such as: technical reports, waveform data, event catalogues, parametric information, algorithms, and software. The mechanics of delivering results to the R&D Testbed is the subject of another symposium presentation.

Finally, R&D Testbed facilities provide researchers with the tools to evaluate R&D results to assess their impact on monitoring capability by providing test environments at whatever scale is appropriate to the evaluation. Testing can range from the full data load of the IMS stations and the full processing environment of the IDC, to highly specific tests confined to special data sets. This wide range of testing environments provides unique testing opportunities for the R&D community. In particular, testing at operational-like scales allows issues to be identified which can go unnoticed in more limited-scale testing. The evaluations of R&D results will be passed to DTRA so that the most promising R&D products can be identified for appropriate action, such as further development or integration into larger systems.

The R&D Testbed is a collaboration between DTRA, the R&D community, and CMR. A wide range of CMR staff, including scientific, software development, testing, and infrastructure support teams are available to support all phases of R&D Testbed activity. Although for many DTRA contractors the delivery of results to the R&D Testbed is mandatory, the R&D Testbed staff will work with contributors on advance planning, scheduling, assisting with test plans and other activities to make the delivery and acceptance process as smooth as possible. Such coordination among all participants is crucial, as the R&D Testbed will be receiving deliveries of various types from nearly ninety different research contracts over the next three years.

### **Key Words:**

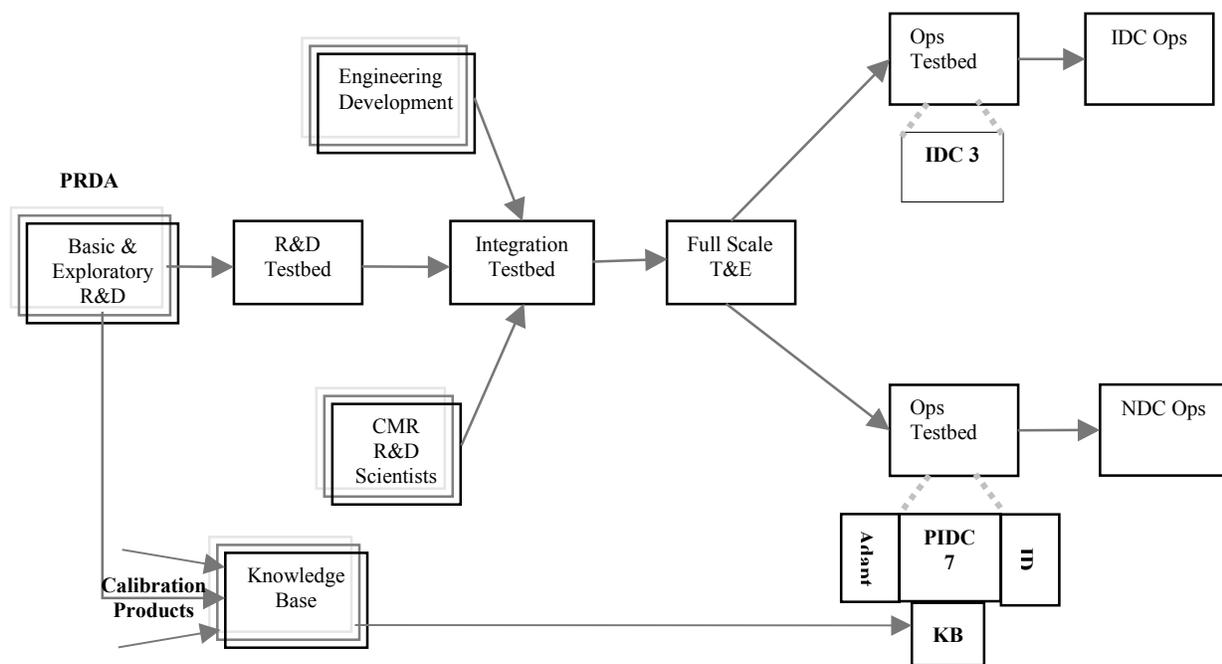
Nuclear explosion monitoring, evaluation, testing, monitoring capability, research and development

## MISSION

The mission of the DTRA CMR R&D Testbed is to provide a research and development environment with test and evaluation facilities at appropriate scales to enable advances, measure progress, and focus resources on the important issues in monitoring and verification. To achieve this mission, a wide range of resources and experience at CMR are available to the nuclear monitoring research community. In the remainder of this paper we highlight some of these resources and how they may be utilized to support both research and development efforts, as well as the test, evaluation, and transition of subsequent research results.

## BACKGROUND

The R&D Testbed at the Defense Threat Reduction Agency's Center for Monitoring Research provides a valuable resource to the nuclear monitoring R&D community. The CMR facility has a long record of research and development activities, supporting both in-house and external research. Further, the processes and procedures utilized by CMR are based on a history of moving solutions from basic R&D to integrated systems. For example, over the past several years CMR has been developing, testing, and transitioning systems to both US government and multi-lateral monitoring organizations (e.g. the US National Data Center located in Florida at Patrick Air Force Base



**Figure 1.** Illustration of the process for moving from basic and exploratory R&D work, on the left of the figure, to final operational systems, on the right side of the figure. As one moves from basic R&D testing to the full-scale test environment, the formalism of the procedures increases, proportional to the scale of the testing. In addition, this figure illustrates how the PIDC 7.0 software release feeds into the NDC operations environment, and Release 3 software (based on PIDC 7.0) feeds into IDC operations environment.

(NDC), and the International Data Centre located in Vienna, Austria (IDC). As illustrated in Figure 1, these efforts have resulted in refined procedures for all stages of the process required to move basic R&D results from the research stage through to operational systems. Extensive testing is conducted at all scales as a routine part of the development and transition process. These tests range from stand-alone and unit tests of individual software components and parametric information, to integration testing on an isolated testbed, up to operational test and evaluation in a full-scale environment.

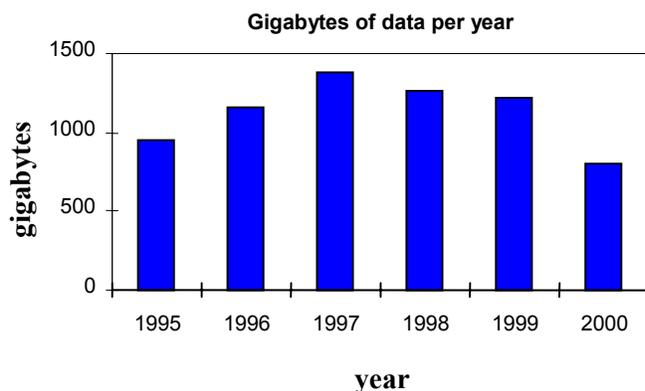
## DATA AND ANALYSIS RESOURCES

The R&D Testbed provides access to a variety of data and products, many of which are produced by the Prototype International Data Center (PIDC) at CMR. A brief listing of some of the more important data resources includes:

- Waveform data (seismic, infrasound, hydroacoustic)
- Radionuclide data
- Event bulletins (from both the PIDC and IDC)
- Special-purpose event and waveform databases
- Web pages

Most data and results can be accessed remotely using AutoDRM or web-based interfaces. See the R&D Testbed web site (<http://www.cmr.gov/rdtb>) for more details and additional links. In addition, open international facilities are available for visiting scientists who wish to directly access research, operations, and development expertise, as well as interact closely with the CMR data archives and databases. Computer and database accounts are also available for direct access to R&D Testbed resources.

CMR currently receives over three gigabytes of data from the IMS and other networks each day and has over five years of archived data. Continuous time series data arrive in near-real-time from primary seismic stations and arrays, as well as from hydroacoustic and infrasound stations. Waveform segments are requested from auxiliary seismic stations, and radionuclide stations send in observations as discrete messages. Figure 2 illustrates the quantity of seismic, hydroacoustic and infrasound data received since 1995. The R&D Testbed provides complete access to the data archives, as well as current data arriving via the International Monitoring System (IMS), though the latter are subject to some restriction.



**Figure 2.** Gigabytes of data in the CMR data archive. The majority of the data, in terms of volume, are comprised of continuous time series data from seismic, hydroacoustic, and infrasound sensors.

Processing results from the PIDC for all of the data collected since 1995 are available on-line and by remote access. These results include preliminary automated event bulletins as well as the analyst Reviewed Event Bulletin (REB). As the IDC has assumed production of daily REBs since February 20, 2000, the PIDC has scaled back to an average of two REBs produced each week. The R&D Testbed provides the research community with access to both PIDC and IDC REBs for every day, from the present back to January 1, 1995, comprising over 100,000 events.

A variety of databases have been assembled for research purposes, and these are best accessed via the web (see the R&D Testbed web site, [www.cmr.gov/rdtb](http://www.cmr.gov/rdtb), for links and instructions). For example, the Nuclear Explosion Database contains a large set of seismic recordings of nuclear tests. The Ground Truth Database contains an extensive catalog of events for which seismic ground truth information, to various levels of certainty, are known. Although the seismic R&D databases are most numerous at CMR, it is important to note that databases exist for all four monitoring technologies: There are hydroacoustic and infrasound research databases, as well as high resolution

gamma-ray spectroscopy and beta-gamma coincidence spectroscopy radionuclide databases. Reports are available to accompany most of the special databases and augment the detail provided on the web site.

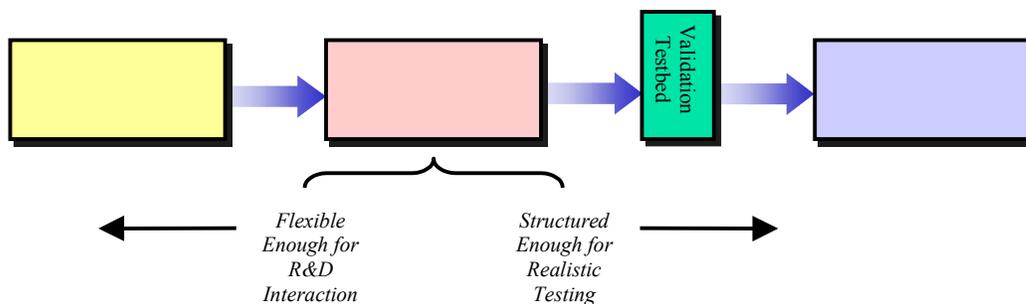
### **DELIVERIES TO THE R&D TESTBED**

The principal investigators of DTRA-sponsored nuclear monitoring research have been instructed to deliver the results of their research to the R&D Testbed. Deliveries take a number of forms, such as reports, raw data (e.g. seismic waveforms), parametric information (e.g. velocity models, station correction tables), and software. The R&D TB verifies that all deliveries meet appropriate acceptance criteria and pass validation tests. Such screening of contributions ensures that deliveries have been made successfully and increases the probability that these results may be successfully used by others. In addition, the R&D Testbed acts as an archive of research results, to prevent their loss and facilitate their distribution within the R&D community. Finally, the accumulation of results through time, and across projects and disciplines, provides the users of the R&D Testbed with a unique research tool.

Various procedures have been established for making deliveries to the R&D Testbed, as well as using the testbed for other purposes, such as testing and evaluating research results (Salzberg, et al, this issue). Test and evaluation procedures are scaled to the level necessary to achieve meaningful results. For example, the most stringent criteria are applied to the use of the full-scale testing environment, while more relaxed criteria are appropriate for limited-scale tests or the test and evaluation of stand-alone applications. An oversight committee prioritizes R&D Testbed activities, as well as reviewing schedules, plans and results.

### **TEST ENVIRONMENTS**

Multiple test environments are available as part of the R&D Testbed. The smallest-scale test environments are readily reconfigured and adapted to the specific needs of a given test. At the largest scale is the capability for full-scale testing under heavy, real-time, data-flow and processing loads. The key benefit of the R&D Testbed's overall test capability is illustrated in Figure 3. Tests can be flexible enough to provide direct R&D interaction and experimentation, yet can be structured enough to simulate a full-scale, mission-critical operational environment.



**Figure 3.** Illustration of the range of test environments available within the R&D Testbed.

Full-scale testing capability is provided by the Prototype Data Center (PDC), which comprises a superset of the functionality of the PIDC. Tests using the PDC are subjected to the full data load and timeliness pressures of a system receiving and processing continuous data running on a high availability basis. Strict configuration control is applied to the full-scale system, with changes subject to the approval of the Configuration Control Board. Such control ensures that changes in behavior of the system, or system output, are well understood, predictable, and repeatable.

A second full-scale, but more configurable, system is provided by the integration testbed. The integration testbed system completely replicates the PDC full-scale system (with the exception of the mass storage system), and provides an environment which can be configured for specific tests. Currently, the integration testbed is used for integrating and testing the full CTBT Monitoring Software System releases for the PIDC, as well as other tests which are incompatible with the more formal PDC environment or where special configurations are required.

Finally, the R&D Testbed provides a broad range of environments for unit tests and stand-alone tests. These tests take advantage of the available resources and processing results and range in scope from single desktops to complete systems.

## **FACILITIES**

A comprehensive infrastructure environment exists at CMR to support the R&D Testbed user community and the R&D Testbed itself. A substantial Commercial Off the Shelf (COTS) software and hardware environment is maintained and documented on the R&D Testbed web site, and is highlighted here:

- Over 60 servers
- Over 90 workstations
- Mass storage systems (DLT, CD-ROM)
- Multiple Oracle instances
- Multiple web sites (open and secure)
- Multiple networks
- Firewall security

A number of these resources can be utilized directly by the R&D community (e.g. accounts are available for direct use of the Oracle database), while others are used to provide community support (e.g. the mass storage system is used to archive and serve data).

R&D Testbed contributors can conduct software demonstrations, as well as train others in the use of their software, in the training and briefing facility. There are multiple large-screen computer projections, from both Sun UNIX and PC hardware platforms, with access to the complete CMR COTS software environment.

## **SUMMARY**

The R&D Testbed makes use of all the facilities, resources, and expertise of CMR for the purpose of improving nuclear monitoring and verification capabilities. This role can be summarized in terms of the following broadly stated goals:

- The R&D Testbed supports the R&D community, from the inception of research through to testing and archiving of results on the R&D testbed itself. Such support can take the form of providing access to current IMS data, production results, IDC results, data archives, and more.
- The R&D Testbed archives research results to ensure important work is not lost and can be shared readily amongst the R&D community.
- The R&D Testbed provides a mechanism for the test, evaluation, and integration of R&D results. Testing can be conducted at various scales, ensuring proper test environments. Such test and evaluation provides the US government with quantitative measures of current monitoring capability, identifying obstacles and establishing expectations for achieving improved capability.